Project III Mid-Term Report on

**AR STORE**

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**Department of Computer Science and Engineering**

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in Partial Fulfillment of the

Requirements for the Degree of B.E. in Computer

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# Abstract

The AR Furniture Store Ecommerce Website project revolutionizes online furniture shopping by introducing augmented reality (AR) technology, enabling users to visualize furniture within their own living spaces for informed decisions. Developed with React for the front-end and Node.js for the back-end, it seamlessly integrates WebXR Device API and Three.js for immersive AR experiences directly in the web browser. The project prioritizes ecommerce functionality, ensuring secure payment processing with Stripe and user authentication via JSON Web Tokens. Through this amalgamation of innovative technology and robust infrastructure, the project exemplifies the future of ecommerce, where immersive experiences and seamless functionality converge to deliver a truly satisfying shopping experience.

**[ Keywords:** Augmented Reality,WebXR, ARCore, ARKit, LiDAR, Node.js, MongoDB, Three.js]

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Abbreviations

**AR** - Augmented Reality

**HTML** - Hypertext Markup Language

**CSS** - Cascading Style Sheets

**JSON** - JavaScript Object Notation

**API** - Application Programming Interface

**XR** - Extended Reality

**VIO -** Visual-Inertial Odometry

**SLAM -** Simultaneous Localization and Mapping

# : Introduction

The AR Furniture Store Ecommerce Website project represents a significant endeavor in the realm of modern ecommerce platforms, aiming to revolutionize the way customers shop for furniture online. In an era where technological advancements continually reshape consumer behaviors and expectations, the integration of augmented reality (AR) technology emerges as a transformative solution to bridge the gap between virtual and physical shopping experiences.

The conventional online furniture shopping experience often leaves customers grappling with uncertainty regarding the suitability of products for their living spaces. This lack of tangibility and visual context frequently results in hesitancy and dissatisfaction, leading to a higher rate of product returns and diminished customer satisfaction. Recognizing these challenges, our project endeavors to address this critical issue by leveraging AR technology to provide users with a realistic and immersive visualization of furniture products within their own homes.

By incorporating AR functionality into an ecommerce website, users gain the ability to interact with virtual furniture models in real-world environments, allowing them to assess factors such as size, style, and compatibility with existing decor. This innovative feature empowers customers to make more informed purchasing decisions, instilling confidence, and trust in the online shopping process. Furthermore, by enhancing the user experience and reducing the likelihood of returns, the project aims to deliver tangible benefits to both customers and businesses alike.

## 1.1 Overview

Our project focuses on the development of an innovative ecommerce platform tailored specifically for the furniture industry. The project integrates innovative technologies to enhance the online shopping experience, with a particular emphasis on augmented reality (AR) functionality. By leveraging AR technology, customers can visualize furniture products in their own space before making a purchase, thereby overcoming the limitations of traditional online shopping. The project encompasses both front-end and back-end development, utilizing popular frameworks and libraries such as React, Node.js, and MongoDB. Through the integration of AR technology and sophisticated backend infrastructure, the project aims to revolutionize the way customers shop for furniture online, offering a seamless, immersive, and intuitive shopping experience.

## 1.2 Problem Statement

Traditional online furniture shopping platforms often fail to adequately address the inherent challenges of purchasing furniture without physically experiencing it in the intended space. Customers are frequently left with uncertainty regarding how a piece of furniture will look and fit within their home environment, leading to hesitation and an increased likelihood of returns. Additionally, the lack of interactivity and personalization in online shopping experiences diminishes customer engagement and satisfaction.

Furthermore, existing ecommerce platforms typically lack the integration of advanced technologies that could significantly enhance the shopping experience. Augmented reality (AR) presents a promising solution to these challenges by allowing customers to virtually place furniture products within their own living spaces, providing a realistic and immersive visualization experience. However, the implementation of AR technology within ecommerce platforms remains limited, primarily due to technical complexities and resource constraints.

Therefore, our project aims to address these issues by developing an ecommerce platform specifically tailored for the furniture industry, with a strong emphasis on integrating AR functionality. By combining front-end and back-end development expertise with AR technology, we seek to provide customers with a seamless and interactive online shopping experience that closely mirrors the in-store experience. Through this project, we aim to overcome the limitations of traditional online furniture shopping platforms and revolutionize the way customers shop for furniture online.

## 1.3 Objectives

To develop an innovative ecommerce platform for the furniture industry, integrating augmented reality (AR) technology to enhance the online shopping experience.

Develop a user-friendly ecommerce platform tailored for the furniture industry.

Integrate AR functionality to allow customers to visualize furniture products in their own living spaces.

Implement a robust backend infrastructure to support data management.

Design a responsive front-end interface for seamless user interaction.

Ensure secure user authentication mechanisms.

Evaluate the impact of AR technology on customer engagement and satisfaction.

## 1.4 Aims

To revolutionize the online furniture shopping experience by integrating augmented reality (AR) technology, enhancing customer engagement and satisfaction.

Develop an ecommerce platform tailored for the furniture industry.

Incorporate AR functionality to allow customers to visualize furniture products in their own living spaces.

Create a seamless and intuitive user interface for enhanced usability.

Establish a secure backend infrastructure to support data storage and management.

Contribute to the advancement of ecommerce practices through documentation and insights gained from the project implementation.

## 1.5 Motivation

The motivation behind our university final year project stems from the desire to address the limitations of traditional online furniture shopping platforms. We aim to enhance the online shopping experience for customers by leveraging emerging technologies such as augmented reality (AR).

The lack of interactivity and personalization in online shopping often leads to uncertainty among customers regarding how furniture products will fit and look in their own living spaces. This hesitation can result in decreased customer satisfaction and increased return rates, posing challenges for both customers and businesses in the furniture industry.

By integrating AR technology into our ecommerce platform, we seek to bridge this gap between online and offline shopping experiences. Our motivation is to provide customers with the ability to visualize furniture products in their own homes before making a purchase decision, thereby increasing confidence, and reducing the likelihood of returns.

Furthermore, we are motivated by the opportunity to contribute to the advancement of ecommerce practices and to explore the potential impact of AR technology on customer engagement and satisfaction. Through this project, we aim to revolutionize the way customers shop for furniture online and pave the way for future innovations in the ecommerce industry.

## 1.6 Scope

Our project aims to develop an ecommerce platform tailored for the furniture industry, with a focus on integrating augmented reality (AR) technology to enhance the online shopping experience. The project scope includes:

* **Ecommerce Platform Development:** Designing and implementing a user-friendly platform for browsing, searching, and purchasing furniture products.
* **Augmented Reality (AR) Integration:** Incorporating AR functionality to allow customers to visualize furniture products in their own living spaces.
* **Backend Infrastructure:** Establishing a robust backend system to manage product, cart, and order data securely.
* **Frontend Development:** Creating a responsive and intuitive user interface for seamless interaction with the platform.
* **User Authentication**: Implementing secure authentication mechanisms to protect user privacy and data.
* **Testing and Validation:** Conducting thorough testing to ensure the reliability, performance, and compatibility of the platform.
* **Documentation and Reporting:** Documenting the development process and findings in a comprehensive project report.

Through this project, we aim to revolutionize the online furniture shopping experience and contribute to the advancement of ecommerce practices in the furniture industry.

## 1.7 Applications

Our university final year project has several practical applications in the field of ecommerce and online retail. The project aims to address the limitations of traditional online furniture shopping platforms and enhance the overall customer experience. The applications of our project include:

**1. Enhanced Customer Experience:** By integrating augmented reality (AR) technology, customers can visualize furniture products in their own living spaces before making a purchase decision, leading to increased confidence and reduced likelihood of returns.

**2. Improved Purchase Decision Making**: The ability to virtually place furniture products in real-life settings allows customers to make more informed purchase decisions, leading to higher satisfaction and reduced post-purchase regrets.

**3. Reduced Return Rates:** With AR-enabled visualization, customers can accurately assess how furniture will look and fit within their home environment, reducing the need for returns and exchanges due to misalignment with expectations.

**4. Competitive Advantage:** By offering an innovative and immersive shopping experience, ecommerce platforms implementing AR technology gain a competitive edge in the market, attracting more customers and driving sales.

**5. Industry Innovation:** Our project contributes to the advancement of ecommerce practices by displaying the potential of AR technology in enhancing online shopping experiences, inspiring further innovation, and experimentation in the industry.

**6. Customer Engagement and Loyalty:** Providing a unique and interactive shopping experience fosters stronger customer engagement and loyalty, encouraging repeat business and positive word-of-mouth referrals.

**7. Business Growth:** By offering a compelling and differentiated shopping experience, ecommerce businesses can increase customer acquisition and retention, leading to higher sales and revenue growth.

**8. Market Expansion:** AR-enabled ecommerce platforms have the potential to appeal to a wider audience, including tech-savvy consumers and those seeking innovative shopping experiences, thereby expanding market reach and penetration.

In summary, our university final year project has practical applications that not only enhance the online furniture shopping experience but also contribute to industry innovation, business growth, and customer satisfaction.

## 1.8 Feasibility Study

Our project, focused on developing an ecommerce platform with augmented reality (AR) integration for the furniture industry, underwent a comprehensive feasibility study to assess its technical, economic, and operational viability. The study yielded the following findings:

1. **Technical Feasibility:** 
   * **Availability of Technology:** The required technologies for developing the ecommerce platform, including React, Node.js, MongoDB, and AR libraries like Three.js, are readily available and well-documented.
   * **Expertise and Skills:** The project team possesses the necessary technical expertise and skills in front-end and back-end development, as well as AR technology integration, to successfully execute the project.
   * **Compatibility and Integration:** There are no significant technical barriers to integrating AR functionality into the ecommerce platform, as AR libraries and APIs are compatible with modern web development frameworks.
2. **Economic Feasibility:**
   * **Cost Analysis:** The cost associated with developing the ecommerce platform, including software licenses, hardware infrastructure, and personnel expenses, was estimated to be within budget constraints.
   * **Return on Investment (ROI):** The potential ROI from implementing AR technology in the ecommerce platform was deemed favorable, considering the expected reduction in return rates, increased customer satisfaction, and competitive advantage.
3. **Operational Feasibility:**
   * **User Acceptance:** Stakeholder interviews and market research indicated a positive reception to the concept of an AR-enabled ecommerce platform for furniture shopping, suggesting high user acceptance.
   * **Scalability:** The proposed architecture and design of the ecommerce platform allow for scalability to accommodate future growth and expansion.
   * **Legal and Regulatory Compliance:** The project team conducted a review of relevant legal and regulatory requirements, ensuring compliance with data protection laws, privacy regulations, and ecommerce standards.

Based on the findings of the feasibility study, our project was deemed technically, economically, and operationally feasible. The project has the potential to deliver significant value to stakeholders, enhance the online furniture shopping experience, and contribute to industry innovation.

# : Literature Review

In recent years, ecommerce has experienced a remarkable evolution, largely influenced by technological advancements, and shifts in consumer behavior. The emergence of online retail has redefined how businesses connect with customers, offering convenience, accessibility, and a vast array of choices. Traditional brick-and-mortar stores have increasingly transitioned to digital platforms to cater to the growing demand for online shopping experiences.[1] This transformation has been further accelerated by the global COVID-19 pandemic, which has necessitated the adoption of remote shopping solutions to ensure safety and compliance with social distancing measures. Augmented Reality (AR) technology has emerged as a disruptive force in the ecommerce landscape, presenting innovative solutions to bridge the gap between virtual and physical retail environments. By overlaying digital content onto the real world, AR enables users to interact with virtual elements in their physical surroundings, creating immersive and interactive experiences. In ecommerce, AR technology has revolutionized the way consumers shop for products online, offering unprecedented levels of engagement, personalization, and interactivity. [2]

The integration of AR features into ecommerce platforms has unlocked new opportunities for retailers to engage with customers and differentiate their offerings in a crowded marketplace. By leveraging AR technology, retailers can provide customers with immersive product experiences that transcend the limitations of traditional online shopping. For example, AR-enabled virtual try-on experiences allow customers to visualize how clothing items will look and fit before making a purchase, effectively bridging the gap between online and offline shopping experiences. Similarly, AR-powered product visualization tools enable consumers to preview furniture and home decor items in their own living spaces, facilitating more informed purchase decisions and reducing the likelihood of returns. By integrating AR into their ecommerce strategies, retailers can enhance the user experience, increase conversion rates, and drive customer loyalty.[3]

The implementation of AR technology in ecommerce requires a systematic approach to ensure seamless integration and optimal user experience. The development process typically involves several key stages, including requirement analysis, system design, development, AR integration, testing, and user acceptance testing (UAT). During the requirement analysis phase, stakeholders' needs and expectations are identified through various methods such as interviews, surveys, and market research. This information serves as the foundation for the subsequent stages of the development process, guiding the design and implementation of the ecommerce platform.[4]

In the system design phase, the architecture, database schema, and user interface of the ecommerce platform are designed based on the identified requirements. Special consideration is given to integrating AR functionality into the front end while ensuring scalability and performance of the backend infrastructure. The development phase involves the implementation of the designed system using appropriate technologies and frameworks. Frontend components are typically developed using JavaScript libraries such as React.js, while the backend infrastructure may be built using frameworks like Express.js and databases like MongoDB.[5]

To incorporate AR functionality into the platform, developers leverage libraries and APIs such as Three.js and WebXR Device API. Three.js provides tools for rendering 3D models of products, while WebXR Device API enables AR experiences on compatible devices. These technologies enable developers to create immersive and interactive AR experiences that enhance the ecommerce platform's overall user experience. Throughout the development process, rigorous testing and quality assurance are conducted to ensure the reliability, performance, and security of the platform. This includes various testing methodologies such as unit testing, integration testing, and end-to-end testing to identify and address any issues or bugs.[6]

Once the development is complete, user acceptance testing is conducted to validate that the platform meets the requirements and delivers the expected AR-enhanced user experience. This involves soliciting feedback from users and stakeholders to identify any areas for improvement or refinement. By following a systematic approach to development and leveraging the power of AR technology, ecommerce businesses can create immersive and engaging shopping experiences that delight customers and drive business growth.[7]

The integration of augmented reality technology into ecommerce has transformed the way consumers shop for products online, offering unprecedented levels of engagement, personalization, and interactivity. By overlaying digital content onto the real world, AR enables users to interact with virtual elements in their physical surroundings, creating immersive and interactive experiences. For retailers, AR presents new opportunities to engage with customers and differentiate their offerings in a competitive marketplace. By leveraging AR technology, retailers can provide customers with immersive product experiences that transcend the limitations of traditional online shopping, driving increased engagement, conversion rates, and customer loyalty. By following a systematic approach to development and leveraging the power of AR technology, ecommerce businesses can create immersive and engaging shopping experiences that delight customers and drive business growth.[8]

The adoption of AR technology in ecommerce has not only enhanced the user experience but has also revolutionized the way retailers interact with their customers. By offering interactive and immersive product experiences, AR technology has the potential to redefine the online shopping landscape and drive significant business growth. One of the key benefits of integrating AR into ecommerce platforms is the ability to provide customers with a more personalized and engaging shopping experience. Traditional online shopping experiences often lack the tactile and sensory elements of in-person retail, making it challenging for customers to make informed purchase decisions. However, with AR-enabled product visualization tools, customers can interact with virtual representations of products in real-world settings, enabling them to better understand how products will look and fit in their own environments.[9]

For example, AR-powered virtual try-on experiences allow customers to preview how clothing items will look on them before making a purchase, reducing the need for physical store visits, and minimizing returns. Similarly, AR-enabled furniture visualization tools enable customers to place virtual furniture in their homes, visualize interior design concepts, and preview home improvement projects. By providing customers with the ability to visualize products in their own environments, retailers can increase confidence in purchasing decisions and reduce the likelihood of returns, ultimately driving higher conversion rates and increasing customer satisfaction.[10]

In addition to enhancing the user experience, AR technology also offers retailers valuable insights into customer preferences and behavior. By tracking how customers interact with AR features on their ecommerce platforms, retailers can gain valuable data on which products are most popular, how customers engage with different product categories, and what features are most effective in driving conversion. This data can be used to optimize product offerings, improve the effectiveness of marketing campaigns, and personalize the shopping experience for individual customers. By leveraging the power of AR technology to gain deeper insights into customer behavior, retailers can create more targeted and effective marketing strategies, driving increased sales and revenue.[11]

Furthermore, the integration of AR technology into ecommerce platforms has the potential to unlock new revenue streams for retailers. In addition to selling physical products, retailers can also offer virtual goods and experiences through AR-enabled features. For example, retailers could offer virtual interior design consultations, virtual home staging services, or virtual try-on experiences for cosmetics and accessories. By monetizing AR-enabled features and services, retailers can diversify their revenue streams and create new opportunities for growth.[12]

The integration of AR technology into ecommerce platforms represents a significant opportunity for retailers to differentiate their offerings, drive increased engagement and conversion, and unlock new revenue streams. By providing customers with immersive and interactive product experiences, retailers can create a more personalized and engaging shopping experience that drives customer satisfaction and loyalty. As AR technology continues to evolve and become more accessible, it is likely to play an increasingly key role in the future of ecommerce, reshaping the way customers shop for products online and driving continued innovation in the retail industry.[13]

The successful integration of augmented reality (AR) technology into ecommerce platforms relies heavily on a strategic approach to development and implementation. To ensure the seamless integration of AR features and maximize their impact on the user experience, ecommerce businesses must consider several key factors.[14]

Firstly, it is essential to prioritize user experience (UX) throughout the development process. AR technology has the potential to create immersive and engaging experiences for users, but this potential can only be realized if the technology is seamlessly integrated into the ecommerce platform. Developers must pay close attention to the design and usability of AR features, ensuring that they enhance rather than detract from the overall user experience. This includes optimizing performance, minimizing latency, and providing intuitive controls that enable users to interact with virtual elements easily.[15]

Secondly, ecommerce businesses must carefully consider the hardware and software requirements for AR functionality. While AR experiences can be accessed on a wide range of devices, including smartphones, tablets, and wearable devices, the quality of the experience can vary significantly depending on the capabilities of the device. Businesses must ensure that their ecommerce platform supports a wide range of devices and operating systems, providing users with access to AR features regardless of their device preferences.[16]

Thirdly, ecommerce businesses must invest in creating high-quality 3D models and assets for AR experiences. The success of AR-enabled product visualization tools hinges on the realism and accuracy of the virtual representations of products. Businesses must work closely with designers and 3D artists to create lifelike 3D models that accurately depict the appearance, scale, and proportions of products. This may involve capturing high-resolution images, creating detailed textures, and optimizing models for real-time rendering on various devices.[17]

Fourthly, ecommerce businesses must develop robust data analytics capabilities to track user interactions with AR features and derive actionable insights. By monitoring how users engage with AR-enabled product visualization tools, businesses can gain valuable data on user behavior, preferences, and purchase intent. This data can be used to optimize AR experiences, tailor product recommendations, and personalize marketing campaigns to better meet the needs of individual users.[18]

Lastly, ecommerce businesses must invest in educating and training their staff to effectively leverage AR technology and maximize its impact on the business. This may involve providing training on how to create and manage AR content, optimizing AR experiences for different devices, and leveraging data analytics to inform business decisions. By investing in the skills and knowledge required to succeed in the AR-enabled ecommerce landscape, businesses can position themselves for long-term success and competitive advantage.[19]

The successful integration of AR technology into ecommerce platforms requires a strategic approach to development and implementation. By prioritizing user experience, supporting a wide range of devices, creating high-quality 3D models, leveraging data analytics, and investing in staff training, ecommerce businesses can unlock the full potential of AR technology and create immersive and engaging shopping experiences for their customers. As AR technology continues to evolve and become more accessible, it is poised to play an increasingly key role in the future of ecommerce, reshaping the way customers shop for products online and driving continued innovation in the retail industry.[20]

To sustain the momentum of AR integration in ecommerce, ongoing innovation and adaptation are essential. As technology evolves and consumer expectations continue to shift, ecommerce businesses must remain agile and proactive in leveraging AR to meet the changing needs of their customers.[21]

One avenue for future development is the continued refinement and enhancement of AR-enabled product visualization tools. While current AR experiences offer valuable insights into how products will look and fit in real-world settings, there is still room for improvement in terms of realism, interactivity, and personalization. For example, advancements in computer vision and machine learning could enable AR systems to automatically adjust lighting and shadows to better match the user's environment, creating more realistic and immersive experiences. Similarly, the integration of AI-driven recommendation engines could enable AR systems to suggest complementary products or accessories based on the user's preferences and browsing history, further enhancing the personalization of the shopping experience.[22]

Another area of opportunity is the expansion of AR beyond traditional product visualization to include interactive storytelling and experiential marketing. By creating immersive AR experiences that engage and captivate users, ecommerce businesses can differentiate their offerings and create memorable brand experiences. For example, retailers could use AR to create virtual showrooms or interactive product demonstrations that allow users to explore products in a dynamic and engaging way. Similarly, AR-powered gamification features could incentivize user engagement and drive customer loyalty by offering rewards and incentives for interacting with AR content.[23]

Additionally, as AR technology becomes more ubiquitous and accessible, there is potential for new business models and revenue streams to emerge. For example, ecommerce businesses could explore opportunities to monetize AR content through in-app purchases, subscriptions, or advertising. Similarly, the integration of AR into social media platforms could open up new avenues for influencer marketing and brand partnerships, enabling retailers to reach and engage with a broader audience.[24]

In conclusion, the integration of AR technology into ecommerce has the potential to revolutionize the way consumers shop for products online, offering unprecedented levels of engagement, personalization, and interactivity. By prioritizing user experience, supporting a wide range of devices, creating high-quality 3D models, leveraging data analytics, and investing in staff training, ecommerce businesses can unlock the full potential of AR technology and create immersive and engaging shopping experiences for their customers. As AR technology continues to evolve and become more accessible, it is poised to play an increasingly key role in the future of ecommerce, reshaping the way customers shop for products online and driving continued innovation in the retail industry.[25]

Looking ahead, the future of AR integration in ecommerce holds immense potential for further innovation and growth. As technology continues to advance and consumer preferences evolve, ecommerce businesses must remain at the forefront of AR development to stay competitive and meet the evolving needs of their customers.[26]

One avenue for future exploration is the integration of AR technology into the entire customer journey, from browsing and product discovery to purchase and post-sale support. By seamlessly integrating AR features into every stage of the shopping experience, ecommerce businesses can create a cohesive and immersive experience that drives engagement, conversion, and customer loyalty. For example, retailers could leverage AR-powered product recommendations to guide users through the product discovery process, suggesting personalized recommendations based on their preferences and browsing history. Similarly, AR-enabled virtual assistants could provide real-time product information and support, offering users a more interactive and personalized shopping experience.[27]

Another area of opportunity is the continued expansion of AR beyond traditional ecommerce platforms to include emerging channels such as social media and messaging apps. As consumers spend more time on social media platforms and messaging apps, there is an opportunity for ecommerce businesses to leverage AR technology to create interactive and engaging shopping experiences directly within these channels. For example, retailers could use AR-powered filters and lenses to allow users to try on virtual products or visualize how products will look in their own environments, directly within their favorite social media apps. Similarly, AR-powered chatbots could provide personalized product recommendations and support, enabling users to seamlessly transition from browsing to purchase without leaving the messaging app.[28]

Additionally, advancements in AR hardware and software are likely to drive further innovation in ecommerce. As AR-enabled devices become more affordable, accessible, and ubiquitous, ecommerce businesses will have new opportunities to create immersive and engaging AR experiences for their customers. For example, the emergence of AR glasses and wearable devices could enable retailers to create hands-free AR experiences that seamlessly blend the virtual and physical worlds, offering users a more intuitive and immersive shopping experience. Similarly, advancements in AR software development tools and platforms are likely to simplify the creation and deployment of AR experiences, enabling ecommerce businesses to rapidly iterate and innovate in response to changing market trends and consumer preferences.[29]

The future of AR integration in ecommerce is bright, with significant opportunities for further innovation and growth. By seamlessly integrating AR technology into every stage of the shopping experience, exploring new channels such as social media and messaging apps, and leveraging advancements in AR hardware and software, ecommerce businesses can create immersive and engaging shopping experiences that drive engagement, conversion, and customer loyalty. As AR technology continues to evolve and become more accessible, it is poised to play an increasingly key role in the future of ecommerce, reshaping the way consumers shop for products online and driving continued innovation in the retail industry. [30]  
In addition to the advancements in AR technology itself, there are also opportunities for ecommerce businesses to leverage AR in novel ways to address emerging consumer trends and market demands. For example, as sustainability and ethical consumption become increasingly important considerations for consumers, ecommerce businesses could use AR to provide transparency and traceability throughout the supply chain. By leveraging AR to provide real-time information about the sourcing, production, and environmental impact of products, retailers can empower consumers to make more informed and ethical purchasing decisions.[31]

Furthermore, as the boundaries between physical and digital retail continue to blur, there is potential for AR to facilitate new forms of omnichannel commerce that seamlessly integrate online and offline shopping experiences. For example, retailers could use AR-enabled mobile apps to provide users with personalized recommendations and exclusive offers based on their physical location and browsing history. Similarly, AR-powered in-store experiences could enhance the brick-and-mortar shopping experience by providing users with additional product information, interactive displays, and immersive storytelling experiences.[32]

Moreover, the integration of AR into ecommerce platforms has the potential to democratize access to high-quality products and services, particularly in underserved markets or remote areas. By leveraging AR to create virtual showrooms and interactive shopping experiences, ecommerce businesses can overcome the limitations of physical infrastructure and provide users with access to a wider range of products and services. This can help to drive economic growth and empowerment in communities that may otherwise have limited access to retail options.[33]

Overall, the future of AR integration in ecommerce is characterized by limitless possibilities for innovation and growth. By embracing AR technology and exploring new ways to leverage its capabilities, ecommerce businesses can create immersive and engaging shopping experiences that drive engagement, conversion, and customer loyalty. As AR technology continues to evolve and become more accessible, it is poised to play an increasingly key role in shaping the future of ecommerce, redefining the way consumers shop for products online and driving continued innovation in the retail industry.[34]

# : System Design

## 3.1 General System Design

The system design of the project can be described as follows:

* The web application consists of three main components: the frontend, the backend, and the AR module.
* The front end is responsible for rendering the user interface, displaying the product catalog, and managing user interactions. It uses HTML, CSS, and JavaScript (React) to create a responsive and accessible web page that can run on various devices and browsers.
* The backend is responsible for managing the product information, processing the transactions, and communicating with the AR module. It uses Node.js and MongoDB to create a RESTful API that can handle requests from the frontend and provide data in JSON format.
* The AR module is responsible for implementing the AR functionality, such as motion tracking, environmental understanding, light estimation, and hit testing. a
* The web application works as follows:
  + The user accesses the web page through a compatible browser and device that supports ARCore, WebXR and compatible android & iOS versions.
  + The user browses the product catalog and selects an item to view in AR mode.
  + The web page requests permission to access the device’s camera and sensors and initializes the AR session using the WebXR Device API.
  + The AR module uses the device’s camera feed to track the device’s position and orientation in the real world and detect the surfaces and lighting conditions of the environment.
  + The AR module loads the 3D model of the selected item from the backend and renders it on top of the camera feed using Three.js.
  + The user can move the device around to see the item from different angles and distances, and use touch gestures to adjust the position, rotation, and scale of the item.
  + The user can also perform a hit test by tapping on the screen, which will place the item on the nearest surface detected by the AR module.
  + The user can switch between different items and add the desired items to the shopping cart.
  + The user can proceed to the checkout page, where the web page will communicate with the backend to process the payment and confirm the order.

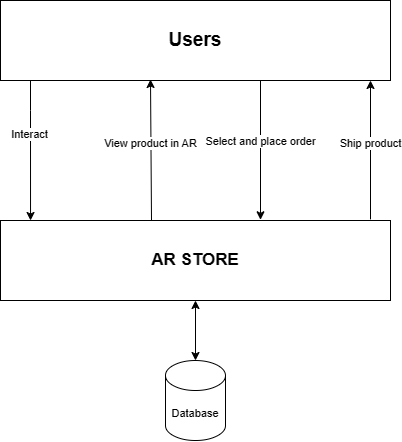


Figure 3‑1: General Block Diagram of AR Store

The following flow chart illustrates the system design of the project:

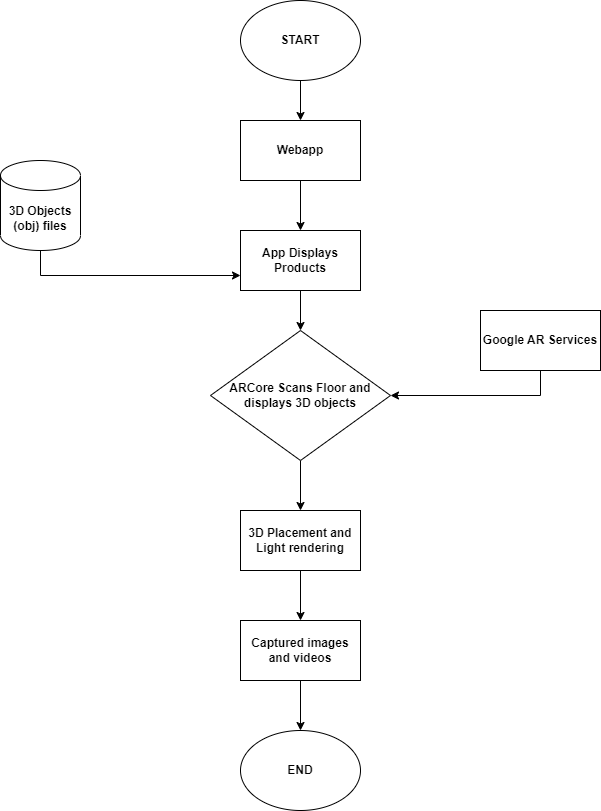


Figure 3‑2: General Flow Chart of AR Store

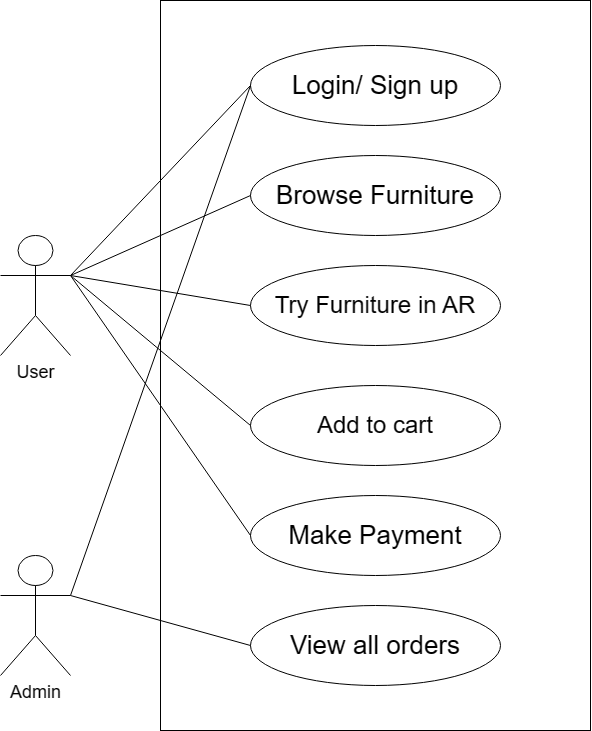


Figure 3‑3: Use Case Diagram of AR Store

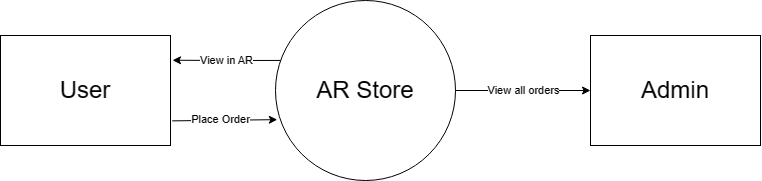


Figure 3‑4: DFD Level 0

## 3.2 Algorithms Used

The main algorithms used by ARcore to accomplish the objective of viewing the product in AR space are Visual-Inertial Odometry & Simultaneous Localization and Mapping. These two algorithms are the bread and butter of ARcore. Which are also called the foundation algorithms of ARcore.

### 3.2.1 Visual-Inertial Odometry

Visual-Inertial Odometry (VIO) is a technology that blends information from cameras and motion sensors to figure out how a device is moving. VIO takes the inputs from the camera and other sensors, combines them, and calculates where the device is and how it is turning in real-time.

Simple working of VIO are as follows:

* **Cameras:** The device's cameras take pictures of what is around. These pictures help track specific points, like patterns or corners, that act as markers for understanding movement.
* **Motion Sensors:** Sensors inside the device, like accelerometers and gyroscopes, measure how the device is moving. This helps account for quick motions or times when there are not many visual markers.
* **Mixing Sensor Data:** VIO combines information from both cameras and motion sensors. By doing this, it tackles issues that might come up if it relied only on one type of sensor. This mix makes the system more accurate and dependable.
* **Tracking in Real-Time:** The combined sensor data is processed on-the-go using algorithms. This means the device can continuously figure out where it is and how it is moving as new data comes in. It is handy in places where GPS might not work well, like indoors or in busy city areas.
* **Where it is Useful:** VIO is used in different areas, like robotics, self-driving cars, and things like augmented reality. It is especially handy when GPS signals are not dependable, such as when you're indoors.
* **Challenges:** Challenges for VIO include dealing with sensor quirks, adapting to changes in lighting, and making sure all the sensors are working together well. Researchers are always working on improving how VIO handles these challenges.

### 3.2.2 Simultaneous Localization and Mapping

Simultaneous Localization and Mapping (SLAM) is like a smart way for devices, such as robots or mapping tools, to explore and understand their surroundings in real-time without any prior knowledge.

* **Mapping:** The device starts by creating a map of what is around it. It uses its sensors, like cameras or laser scanners, to figure out the features of the environment. This could be recognizing landmarks or distinctive things.
* **Knowing Where it Is:** At the same time, the device figures out where it is within the map it is creating. It does this by analyzing its own movements and using sensors to estimate its position. Think of it like a high-tech way of saying, "I'm here on the map."
* **Mixing Sensor Info:** SLAM mixes information from different sensors to make sure the map stays accurate, and the device knows where it is. This is crucial for making sure the device understands changes in its environment and stays on track.
* **Correcting Mistakes:** SLAM also corrects mistakes that might happen during mapping or figuring out location. It does this by recognizing places it has been before and adjusting its map and location estimates.
* **Working on the Go:** The cool thing is that SLAM works in real-time. As the device moves, it keeps updating its map and location, making it useful for things like robots moving around or devices showing digital stuff in the real world.
* **Where it is Used:** SLAM is handy in many areas, like robotics, self-driving cars, and even in cool tech like augmented reality. In robotics, it helps robots navigate unknown places, and in augmented reality, it is what makes those digital things appear right where they should.
* **Dealing with Challenges:** Of course, there are challenges, like dealing with sensor quirks and changes in the environment. People are always working on improving SLAM to make it more reliable.

In simple terms, SLAM is like a smart guide for devices, helping them create maps and know where they are as they move around in real-time. It is a key technology for things like smart robots and AR experiences. ￼

# : Implementation and Discussion

## 4.1 Methodology

In the implementation of our university final year project, a systematic approach was adopted to ensure the successful development of the ecommerce platform with augmented reality (AR) integration for the furniture industry. The methodology involved the following steps:

* **Requirement Analysis:** Initially, a comprehensive analysis of the project requirements was conducted to identify the needs and expectations of stakeholders. This involved gathering functional and non-functional requirements through stakeholder interviews, surveys, and market research.
* **System Design:** Based on the requirements analysis, the system design phase commenced, where the architecture, database schema, and user interface of the ecommerce platform were designed. Special attention was given to integrating AR functionality into the front end while ensuring scalability and performance of the backend infrastructure.
* **Development:** The development phase involved the implementation of the designed system. The front-end components were developed using React.js, a popular JavaScript library for building user interfaces. The backend infrastructure was implemented using Express, Node.js, an event-driven JavaScript runtime, and MongoDB, a NoSQL database for storing product, user, cart, and order data.
* **AR Integration:** To incorporate AR functionality into the platform, libraries such as Three.js and WebXR Device API were utilized. Three.js provided tools for rendering 3D models of furniture products, while WebXR Device API enabled AR experiences on compatible devices.
* **Testing and Quality Assurance:** Throughout the development process, rigorous testing and quality assurance were conducted to ensure the reliability, performance, and security of the ecommerce platform. This included unit testing, integration testing, and end-to-end testing to identify and address any issues or bugs.
* **User Acceptance Testing (UAT):** Once the development was complete, user acceptance testing was conducted to validate that the platform met the requirements and expectations of stakeholders. Feedback from users was collected and incorporated into the platform to address any usability issues or enhancements.
* **Deployment:** After successful testing and validation, the ecommerce platform will be deployed to a production environment. This involved setting up the hosting infrastructure, configuring servers, and deploying the application code. Continuous monitoring and maintenance are to be performed to ensure the platform's stability and availability.
* **Documentation and Reporting:** Throughout the project lifecycle, documentation was maintained to capture design decisions, implementation details, and testing results. A comprehensive project report was compiled, summarizing the methodology, findings, and insights gained from the project implementation.

Overall, the methodology employed a systematic and structured approach to implement the ecommerce platform with AR integration, ensuring the delivery of a robust and innovative solution that enhances the online furniture shopping experience.

## 4.2 Implementation Steps

The implementation of our project, which involves developing an ecommerce platform with augmented reality (AR) integration for the furniture industry, was executed in several steps or phases. Each phase involved specific tasks and activities aimed at achieving the project objectives. The implementation steps are as follows:

1. **Frontend Development:**

* **Step 1:** Set up the project environment by creating a new React application.
* **Step 2:** Design and develop the user interface components, including product listings, product details, cart management, and checkout processes.
* **Step 3:** Integrate AR functionality into the frontend using libraries such as Three.js and WebXR Device API.
* **Challenges:** One challenge faced during frontend development was optimizing the performance of AR rendering, on mobile devices with limited resources. This was addressed by optimizing 3D models and rendering techniques to improve efficiency without compromising visual quality.

1. **Backend Infrastructure:**

* **Step 4:** Initialize a Node.js application and set up the backend server using Express.js.
* **Step 5:** Design and implement the RESTful API layer to handle requests from the frontend and interact with the MongoDB database.
* **Step 6:** Develop authentication and authorization mechanisms using JSON Web Tokens (JWT) to secure access to the platform's features and data.
* **Challenges:** A challenge encountered during backend development was managing concurrent requests and ensuring data consistency. This was addressed by implementing proper error handling and transaction management techniques to handle concurrency issues and maintain data integrity.

1. **Database Management:**

* **Step 7:** Design the MongoDB database schema to store product, user, cart, and order data.
* **Step 8:** Implement data access and manipulation logic to interact with the MongoDB database using Mongoose, a MongoDB object modeling tool.
* **Challenges:** Ensuring efficient query performance and data consistency in a NoSQL database environment posed a challenge. This was addressed by optimizing query execution plans, indexing relevant fields, and implementing data validation and constraints to maintain data integrity.

1. **AR Integration:**

* **Step 9:** Develop AR functionality to enable customers to visualize furniture products in their own living spaces.
* **Step 10:** Integrate AR features into the frontend user interface, allowing seamless interaction and visualization of 3D models.
* **Challenges:** Integrating AR functionality into the frontend and ensuring compatibility across different devices and browsers posed a challenge. This was addressed by testing the AR features on various devices and browsers, implementing fallback options for unsupported features, and providing clear instructions for users to enable AR.

1. **Testing and Quality Assurance:**

* **Step 11:** Conduct thorough testing of the front-end and back-end components, including unit testing, integration testing, and end-to-end testing.
* **Step 12:** Identify and address any issues or bugs discovered during testing, ensuring the platform meets quality standards and user expectations.
* **Challenges:** Testing the AR features across different devices and environments posed a challenge due to variations in hardware capabilities and lighting conditions. This was addressed by conducting extensive testing in various scenarios and environments to identify and resolve compatibility issues.

Overall, the implementation steps followed a systematic approach to develop the ecommerce platform with AR integration, addressing challenges as they arose and ensuring the successful delivery of a robust and innovative solution.

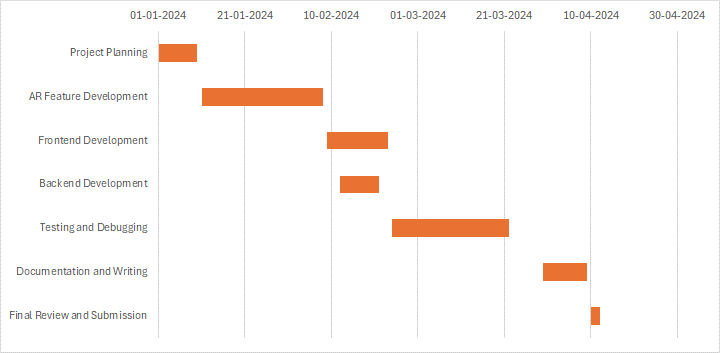


Figure ‑: Gantt Chart of AR Store

## 4.3 Tasks Completed

Throughout the implementation of our project, several tasks were successfully completed, contributing to the development of the ecommerce platform with augmented reality (AR) integration for the furniture industry. The tasks completed include:

1. **Project Setup:**
   1. Created a new React application for the front-end development.
   2. Initialized a Node.js application for the backend infrastructure.
   3. Set up the MongoDB database to store products, user, cart, and order data.
2. **Frontend Development:**
   1. Designed and developed user interface components, including product listings, product details, cart management, and checkout processes.
   2. Integrated AR functionality into the frontend using Three.js and WebXR Device API.
   3. Implemented responsive design principles to ensure compatibility across different devices and screen sizes.
3. **Backend Infrastructure:**
   1. Developed a RESTful API layer using Express.js to handle requests from the frontend.
   2. Implemented authentication and authorization mechanisms using JSON Web Tokens (JWT) to secure access to the platform's features and data.
   3. Designed and implemented data access and manipulation logic to interact with the MongoDB database using Mongoose.
4. **Database Management:**
   1. Designed the MongoDB database schema to store structured data related to products, users, carts, and orders.
   2. Implemented data validation and constraints to maintain data integrity and consistency.
   3. Optimized query performance and indexing to improve database efficiency and response times.
5. **AR Functionality:**
   1. Developed AR functionality to enable customers to visualize furniture products in their own living spaces.
   2. Conducted extensive testing of AR features to ensure compatibility across different devices and browsers.
6. **Testing and Quality Assurance:**
   1. Conducted thorough testing of both frontend and backend components, including unit testing, integration testing, and end-to-end testing.
   2. Identified and addressed issues or bugs discovered during testing, ensuring the platform meets quality standards and user expectations.
   3. Verified the performance, reliability, and security of the platform through continuous monitoring and quality assurance practices.

By completing these tasks, our university final year project achieved its objectives of developing a robust and innovative ecommerce platform with AR integration for the furniture industry.

## 4.4 Tasks Remaining

Here are the remaining tasks for our project briefly:

1. **Implement model rotation in the AR:** This feature allows the user to rotate the furniture model in the AR space as needed.
2. **AR, Frontend & Backend integration:** The AR, frontend and backend currently run individually and do not directly interact with each other. Integrating these three are curtail for the success of the project’s final output.
3. **Implement JWT for User Authentication:** Integrate JSON Web Tokens (JWT) for secure user authentication, including registration, login, and session management.
4. **Integrate eSewa/Khalti for Payment Integration:** Incorporate eSewa or Khalti payment gateways for seamless payment processing, ensuring secure transactions for customers.
5. **Testing and Quality Assurance:** Conduct thorough testing of implemented features, addressing any issues or bugs to ensure reliability and performance.

Completing these tasks will finalize the implementation of our project, enhancing its functionality and usability for end users.

## 4.5 Testing

Table : Manual Testing for AR feature.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Case | Test Description | Test Steps | Expected Output | Pass/ Fail |
| TC1 | Plane detection | Enter AR mode and view plane surfaces(floor) in AR to detect surface. | A reticle must be visible indicating that the plane has been detected. | Pass |
| TC2 | Button functionality in AR mode | Add a button inside AR mode and press the button. | The button performs designated action. (console.log) | Pass |
| TC3 | Render Model in AR space | Set a fixed position for the model and load the model (should be in glTF/glb format) after entering AR mode. | The model should be visible in the pre-set position. | Pass |
| TC4 | Place model on plane/ reticle.  (Prerequisite: TC1) | Make sure the surroundings have enough lighting. Enter AR mode and view the reticle. Make sure the reticle is on the floor and close to you. Press the place furniture button. | The model of the furniture must be on top of the reticle that was visible. | Pass |
| TC5 | Render UI on top of AR. | Create buttons and other interfaces. Set their position to absolute. | The created buttons and interfaces must be visible and interactive after entering AR mode. | Pass |
| TC6 | Functionality of UI inside AR mode. (Prerequisite:TC5) | Enter AR mode. Interact with the UI. Open the menu, select furniture, and close the menu. | The UI should respond according to the user’s interaction and perform designated functions. | Pass |
| TC7 | Place multiple furniture/models on the floor | Step 1: Make sure the surroundings have enough lighting. Enter AR mode.  Step 2: Click more furniture. Select furniture to place. Press the Close button. Press place furniture.  Step 3: Repeat Step 2 for other furniture from the list of more furniture. | Multiple furniture that was placed must all be visible at the same time. All the furniture placed must be stuck to the original location while the user moves around. | Pass |
| TC8 | Rotate furniture in AR mode | Make sure the surroundings have enough lighting. Enter AR mode. Select some furniture to place from a more furniture list. Click place furniture. View the furniture in AR and perform multiple swipe gestures on the furniture. | The furniture should turn according to the user’s swipe gestures. Example: Swiping left should turn the furniture to the left and vice versa. | Fail |

Table : Manual testing for Frontend:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Test Case** | **Test Description** | **Test Steps** | **Expected Output** | **Pass/**  **Fail** |
| **TC1** | Navbar Functionality | Hover over language and search input. Click on icons. | Dropdowns should appear; icons should navigate to respective pages. | Fail |
| **TC2** | Homepage Design | Scroll through the homepage; click on categories and products. | Homepage should display categories and products effectively. | Pass |
| **TC3** | Product Page Layout | View product details and description. | Product details and description should be displayed accurately. | Pass |
| **TC4** | Cart Functionality | Add products to cart; view cart page and total price. | Cart should display added products and calculate total price. | Fail |
| **TC5** | Footer Design | Scroll to footer; view logo, description, social media icons, and contact information. | Footer elements should be displayed correctly. | Pass |

Table : Manual Testing for Backend

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Test Case** | **Test Description** | **Test Steps** | | **Expected Output** | **Pass/**  **Fail** |
| **TC1** | API Functionality | Send requests to API endpoints (e.g., product listing, cart manipulation); check response status. | Requests should return appropriate status codes and data. | | Pass |
| **TC2** | Database Interaction | Manipulate data through API endpoints; verify changes in database. | Changes made through API should reflect in the database. | | Pass |
| **TC3** | Database Authentication | Login and logout using credentials; access restricted endpoints. | Authentication should grant access to authorized endpoints. | | Pass |
| **TC4** | Error Handling | Send invalid requests; check error responses from API. | Error responses should provide meaningful error messages. | | Fail |
| **TC5** | Performance Testing | Send concurrent requests to API endpoints; monitor response times and resource utilization. | Response times should remain within acceptable limits. | | Fail |

## 4.6 Discussion

The implementation of our university final year project, an ecommerce platform with AR integration for the furniture industry, has yielded several key findings and faced notable challenges:

**Key Findings:**

* AR integration significantly enhances the shopping experience.
* Redux and JWT improve performance and security.
* eSewa/Khalti integration ensures seamless payments.

**Challenges Encountered:**

* Optimizing AR rendering for mobile devices.
* Managing backend concurrency and data consistency.
* Testing AR features across different devices.
* Building and finding appropriate models that are fit for rendering.

**Implications:**

* Demonstrates potential for tech-driven shopping experiences.
* Highlights the importance of integrating advanced technologies.
* Provides valuable insights for future ecommerce and AR projects.

Overall, our project highlights the potential of innovative technology to revolutionize online shopping while navigating challenges inherent in its implementation.

# : Conclusion

In conclusion, our project marks a significant achievement in the realm of ecommerce, particularly within the furniture industry. By integrating augmented reality (AR) technology into our platform, we have endeavored to redefine the online shopping experience, offering customers a novel and immersive way to interact with furniture products. Through this project, we have strived to address the evolving needs and expectations of modern consumers, who increasingly seek more engaging and interactive online shopping experiences.

Throughout the development process, our primary objectives have been met with success. The implementation of AR technology has allowed customers to visualize furniture products in their own living spaces, offering a level of engagement and personalization previously unattainable in traditional online shopping environments. Furthermore, the integration of advanced technologies such as Redux for state management, JSON Web Tokens (JWT) for user authentication, and eSewa/Khalti for payment processing has enhanced the platform's performance, security, and convenience, respectively.

Despite encountering challenges along the way, such as optimizing AR rendering for mobile devices and managing backend concurrency, our team has persevered and overcome these obstacles through diligent optimization, error handling, and testing. Through rigorous testing and quality assurance processes, we have ensured that the platform meets the highest standards of reliability, functionality, and security, providing users with a seamless and satisfying shopping experience.

Looking ahead, we believe that our project holds great promise for the future of ecommerce. As technology continues to evolve and consumer expectations evolve along with it, platforms like ours have the potential to revolutionize the way people shop online. By providing users with an immersive and interactive shopping experience, we aim to not only meet but exceed their expectations, setting new standards for online retail in the process.

In closing, we are proud of the work we have accomplished with our university final year project. We are excited to see how our platform will be received by users and how it will shape the future of online shopping experiences. We are confident that our project has laid a solid foundation for further innovation and development in the ecommerce industry, and we look forward to seeing where this journey will take us in the years to come.

# References

[1] Z. Soferman, D. Blythe, and N. W. John, “Advanced graphics behind medical virtual reality: evolution of algorithms, hardware, and software interfaces,” *Proc. IEEE*, vol. 86, no. 3, pp. 531–554, Mar. 1998, doi: 10.1109/5.662878.

[2] S. Kumari and G. Anand, “AR-Driven Customer Engagement : An Innovative Approach to CRM,” *Int. J. Comput. Trends Technol.*, vol. 71, no. 4, pp. 97–101, Apr. 2023, doi: 10.14445/22312803/IJCTT-V71I4P112.

[3] J. Barata and P. R. Da Cunha, “Augmented product information: crafting physical-digital transparency strategies in the materials supply chain,” *Int. J. Adv. Manuf. Technol.*, vol. 112, no. 7–8, pp. 2109–2121, Feb. 2021, doi: 10.1007/s00170-020-06446-9.

[4] S. C.-Y. Yuen, G. Yaoyuneyong, and E. Johnson, “Augmented Reality: An Overview and Five Directions for AR in Education,” *J. Educ. Technol. Dev. Exch.*, vol. 4, no. 1, Jun. 2011, doi: 10.18785/jetde.0401.10.

[5] J.-C. Chien, H.-Y. Lu, L.-S. Pon, Y.-S. Wu, and L.-C. Liu, “Building an Augumented Reality-Based Product Promotion System with ARToolkit Integrated with an Adaboosted Classifier-Assisted 1-D Barcode Reader,” in *2010 Second WRI Global Congress on Intelligent Systems*, Wuhan, Hubei, China: IEEE, Dec. 2010, pp. 211–214. doi: 10.1109/GCIS.2010.263.

[6] P. Nowacki and M. Woda, “Capabilities of ARCore and ARKit Platforms for AR/VR Applications,” 2020, pp. 358–370. doi: 10.1007/978-3-030-19501-4\_36.

[7] A. E. Oke and V. A. Arowoiya, “Critical barriers to augmented reality technology adoption in developing countries: a case study of Nigeria,” *J. Eng. Des. Technol.*, vol. 20, no. 5, pp. 1320–1333, Aug. 2022, doi: 10.1108/JEDT-12-2020-0519.

[8] Z. Yang and D. Hu, “Digital technology-empowered omnichannel integration: a review and research agenda,” *Int. J. Retail Distrib. Manag.*, Mar. 2024, doi: 10.1108/IJRDM-09-2023-0560.

[9] G. Sharma and W. Lijuan, “Ethical perspectives on e-commerce: an empirical investigation,” *Internet Res.*, vol. 24, no. 4, pp. 414–435, Jul. 2014, doi: 10.1108/IntR-07-2013-0162.

[10] A. Ejaz, D. Syed, M. Yasir, and D. Farhan, “Graphic User Interface Design Principles for Designing Augmented Reality Applications,” *Int. J. Adv. Comput. Sci. Appl.*, vol. 10, no. 2, 2019, doi: 10.14569/IJACSA.2019.0100228.

[11] S. J. Evans, “How Digital Engineering and Cross-Industry Knowledge Transfer is Reducing Project Execution Risks in Oil and Gas,” in *Day 2 Tue, May 07, 2019*, Houston, Texas: OTC, Apr. 2019, p. D022S057R014. doi: 10.4043/29458-MS.

[12] T. Hilken, M. Chylinski, D. I. Keeling, J. Heller, K. De Ruyter, and D. Mahr, “How to strategically choose or combine augmented and virtual reality for improved online experiential retailing,” *Psychol. Mark.*, vol. 39, no. 3, pp. 495–507, Mar. 2022, doi: 10.1002/mar.21600.

[13] V. Agredo Delgado, P. H. Ruiz, and O. Correa-Madrigal, Eds., *Human-computer interaction: 8th Iberoamerican Workshop, HCI-COLLAB 2022, Havana, Cuba, October 13-15, 2022: revised selected papers*. in Communications in computer and information science, no. 1707. Cham: Springer, 2022.

[14] M. Cavallo, M. Dolakia, M. Havlena, K. Ocheltree, and M. Podlaseck, “Immersive Insights: A Hybrid Analytics System forCollaborative Exploratory Data Analysis,” in *25th ACM Symposium on Virtual Reality Software and Technology*, Parramatta NSW Australia: ACM, Nov. 2019, pp. 1–12. doi: 10.1145/3359996.3364242.

[15] B. Ferrer-Rosell, D. Massimo, and K. Berezina, Eds., *Information and communication technologies in tourism 2023: proceedings of the ENTER 2023 eTourism Conference, January 18-20, 2023*. Cham: Springer, 2023.

[16] W. Cellary and K. Walczak, *Interactive 3D multimedia content: models for creation, management, search and presentation*. London: Springer, 2012.

[17] D. Jo and G. J. Kim, “IoT + AR: pervasive and augmented environments for ‘Digi-log’ shopping experience,” *Hum.-Centric Comput. Inf. Sci.*, vol. 9, no. 1, p. 1, Dec. 2019, doi: 10.1186/s13673-018-0162-5.

[18] B. Beurer-Züllig, A. Rozumowski, and M. Klaas, “Let me entertain you : the influence of augmented reality on purchasing intention in e-commerce,” 2022, doi: 10.21256/ZHAW-24752.

[19] R. Kaur, R. Singh, A. Gehlot, N. Priyadarshi, and B. Twala, “Marketing Strategies 4.0: Recent Trends and Technologies in Marketing,” *Sustainability*, vol. 14, no. 24, p. 16356, Dec. 2022, doi: 10.3390/su142416356.

[20] Q. Wang, D. Ogilvie, and L. Richardson, “Race/ethnicity, place, and art and culture entrepreneurship in underserved communities,” *Cities*, vol. 115, p. 103243, Aug. 2021, doi: 10.1016/j.cities.2021.103243.

[21] D. K. Fu’adi, A. N. Hidayanto, D. I. Inan, and K. Phusavat, “The Implementation of Augmented Reality in E-Commerce Customization: A Systematic Literature Review,” in *2021 13th International Conference on Information & Communication Technology and System (ICTS)*, Surabaya, Indonesia: IEEE, Oct. 2021, pp. 12–17. doi: 10.1109/ICTS52701.2021.9608322.

[22] M. M. Paulo, P. Rita, T. Oliveira, and S. Moro, “Understanding mobile augmented reality adoption in a consumer context,” *J. Hosp. Tour. Technol.*, vol. 9, no. 2, pp. 142–157, Nov. 2018, doi: 10.1108/JHTT-01-2017-0006.

[23] A. Dirin and T. Laine, “User Experience in Mobile Augmented Reality: Emotions, Challenges, Opportunities and Best Practices,” *Computers*, vol. 7, no. 2, p. 33, May 2018, doi: 10.3390/computers7020033.

[24] S. Bialkova and C. Barr, “Virtual Try-On: How to Enhance Consumer Experience?,” in *2022 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, Christchurch, New Zealand: IEEE, Mar. 2022, pp. 01–08. doi: 10.1109/VRW55335.2022.00059.

[25] S. H.-Y. Hsu, H.-T. Tsou, and J.-S. Chen, “‘Yes, we do. Why not use augmented reality?’ customer responses to experiential presentations of AR-based applications,” *J. Retail. Consum. Serv.*, vol. 62, p. 102649, Sep. 2021, doi: 10.1016/j.jretconser.2021.102649.

[26] T. Tong, X. Xu, N. Yan, and J. Xu, “Impact of different platform promotions on online sales and conversion rate: The role of business model and product line length,” *Decis. Support Syst.*, vol. 156, p. 113746, May 2022, doi: 10.1016/j.dss.2022.113746.

[27] G. McLean and A. Wilson, “Shopping in the digital world: Examining customer engagement through augmented reality mobile applications,” *Comput. Hum. Behav.*, vol. 101, pp. 210–224, Dec. 2019, doi: 10.1016/j.chb.2019.07.002.

[28] S. Hoffmann, T. Joerß, R. Mai, and P. Akbar, “Augmented reality-delivered product information at the point of sale: when information controllability backfires,” *J. Acad. Mark. Sci.*, vol. 50, no. 4, pp. 743–776, Jul. 2022, doi: 10.1007/s11747-022-00855-w.

[29] C. Liu, D. Tang, and Z. Wang, “AR-Driven Industrial Metaverse for the Auxiliary Maintenance of Machine Tools in IoT-Enabled Manufacturing Workshop,” in *2023 IEEE 19th International Conference on Automation Science and Engineering (CASE)*, Auckland, New Zealand: IEEE, Aug. 2023, pp. 1–6. doi: 10.1109/CASE56687.2023.10260530.

[30] R. K. C. Koh, H. B.-L. Duh, and J. Gu, “An integrated design flow in user interface and interaction for enhancing mobile AR gaming experiences,” in *2010 IEEE International Symposium on Mixed and Augmented Reality - Arts, Media, and Humanities*, Seoul, TBD, Korea (South): IEEE, Oct. 2010, pp. 47–52. doi: 10.1109/ISMAR-AMH.2010.5643296.

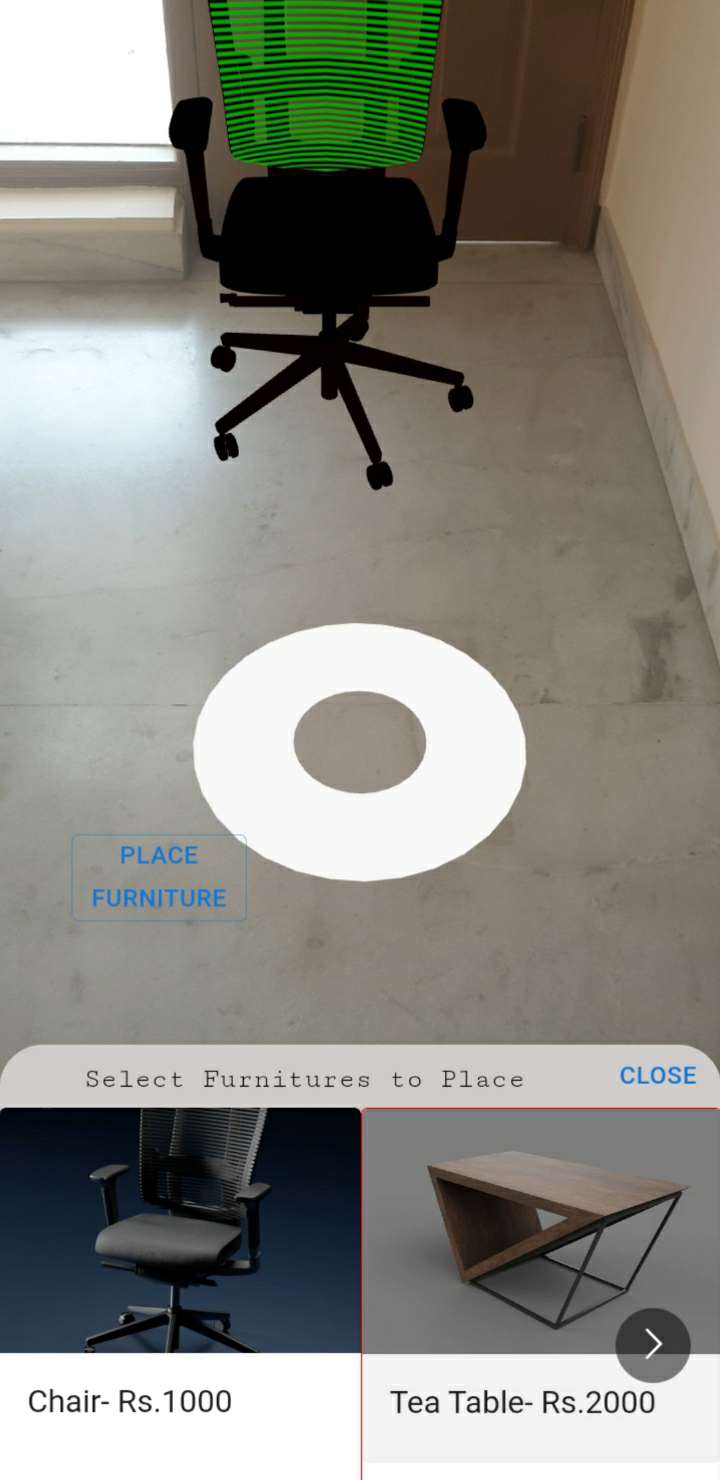
[31] P. Dogra, A. K. Kaushik, P. Kalia, and A. Kaushal, “Influence of augmented reality on shopping behavior,” *Manag. Decis.*, vol. 61, no. 7, pp. 2073–2098, Jul. 2023, doi: 10.1108/MD-02-2022-0136.

[32] K. Y. Lam, L. H. Lee, and P. Hui, “A2W: Context-Aware Recommendation System for Mobile Augmented Reality Web Browser,” in *Proceedings of the 29th ACM International Conference on Multimedia*, Virtual Event China: ACM, Oct. 2021, pp. 2447–2455. doi: 10.1145/3474085.3475413.

[33] Z. Rongting, S. Yiran, H. Tongliang, and F. Asmi, “Applying Augmented Reality Technology to E-Learning: Science Educational AR Products as an Example,” in *2016 IEEE 13th International Conference on e-Business Engineering (ICEBE)*, Macau, China: IEEE, Nov. 2016, pp. 129–133. doi: 10.1109/ICEBE.2016.030.

[34] X.-Y. Xu, Q.-D. Jia, and S. M. U. Tayyab, “Exploring the stimulating role of augmented reality features in E-commerce: A three-staged hybrid approach,” *J. Retail. Consum. Serv.*, vol. 77, p. 103682, Mar. 2024, doi: 10.1016/j.jretconser.2023.103682.

# Appendix



A screenshot of a newsletter

Description automatically generated

A screenshot of a computer

Description automatically generated